

DESIGN OF AN AUTOMATED SYSTEM FOR MANAGING THE STARTUP AND OPERATING SEQUENCES OF AN INDUSTRIAL BOILER USING A ZELIO LOGIC PLC

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DOI: 10.51865/JPGT.2026.02.09

ABSTRACT

This article presents the design and simulation of an automated system for managing the startup and operating sequences of an industrial boiler using a Zelio Logic programmable logic controller (PLC). In industrial environments, managing the various phases of boiler operation (startup, pre-ventilation, ignition, heating, and shutdown) is essential to ensuring the safety, reliability, and energy efficiency of the process. Traditional control methods, which are often manual or semi-automated, still have significant limitations related to human error and a lack of coordination between sequences. The approach adopted is based on a functional analysis of the system and its modeling using a GRAFCET to structure the control logic. The system is then implemented in Zelio Soft 2 using sequential logic based on SET/RESET flip-flops, timers, and logic functions. Simulation results show that the system correctly executes the boiler's various phases with good coordination of outputs (ventilation, ignition, and heating). In conclusion, the use of the Zelio Logic API provides a simple, reliable, and cost-effective solution for the automation of industrial boilers, with potential for future development toward remote monitoring and intelligent performance optimization.

Keywords: industrial boiler, automation, Zelio Logic, PLC, timing, sequential control.

INTRODUCTION

Industrial boilers are widely used in the petroleum, food processing, mining, and manufacturing industries for the production of steam or hot water [4-12]. Start-up and shutdown procedures involve several successive operations that must be performed in a specific order to avoid the risk of explosion, overheating, or mechanical failure [16].

Traditionally, these operations are performed manually by operators. However, this approach carries risks associated with human error and delays in execution. The integration of a programmable logic controller (PLC) makes it possible to automate these sequences while enhancing process safety [1],[2],[5]. This article proposes the implementation of an automated

boiler control system using the Zelio Logic programmable logic controller. In many industrial facilities, boiler startup operations are still partially manual, leading to operational errors, excessive energy consumption, and the risk of malfunctions [17].

Recent studies have demonstrated the effectiveness of programmable logic controllers (PLCs) in sequential control and industrial automation [18–20]. Systems based on programmable logic controllers have also been successfully implemented for the control and monitoring of industrial steam boilers [21],[22].

Furthermore, numerical modeling and automation studies have contributed to improving the efficiency, reliability, and safety of boilers [23–25]. In the oil and gas sector, automated systems based on programmable logic controllers have proven their value for the monitoring and control of industrial processes [26–28].

This article proposes the implementation of an automated control system for a boiler using the Zelio Logic programmable logic controller. The article is based on the design of an automated system that manages the startup and operating sequences of an industrial boiler using a Zelio Logic PLC.

In many industrial facilities, boiler startup operations are still partially manual. This situation leads to:

- operational errors;
- excessive energy consumption;
- risks of burner malfunction;
- difficulties in monitoring the process;
- increased maintenance costs.

How can the various operating sequences of an industrial boiler be automated to improve its safety, reliability, and energy efficiency ?

To address this issue, this paper proposes an automated sequential control approach based on GRAFCET functional modeling implemented on a Schneider Electric Zelio Logic programmable logic controller (PLC). By utilizing sequential logic, SET/RESET memory functions, and precise timing control in Zelio Soft 2, the proposed system coordinates critical operating phases – including pre-ventilation, burner ignition, flame monitoring, and steady-state heating – while enforcing safety interlocks to prevent operational errors and hazardous conditions.

METHODOLOGY

The methodology adopted for the design of the automated control system for the industrial boiler was structured around several key steps (Figure 1). A preliminary study of the boiler's operation identified the various phases of the cycle (initialization, pre-ventilation, ignition, heating, operation, and safe shutdown). A GRAFCET diagram (Figure 2) was then developed to model the control sequence in a structured manner.

The program was developed using Zelio Soft 2, incorporating SET/RESET flip-flops, timers, and logic functions to ensure the proper sequencing of the steps. Finally, simulations were conducted to validate the overall operation and verify compliance with safety requirements.

SYSTEM DESCRIPTION

The developed system includes:

- Inputs: Start button (I1), Stop button (I2), Temperature sensor, Flame detector, Pressure sensor,
- Outputs: Q1: Main power supply, Q2: Pre-ventilation fan, Q3: Burner ignition, and Q4: Heat output,
- PLC: Zelio Logic by Schneider Electric,
- Software: Zelio Soft 2.

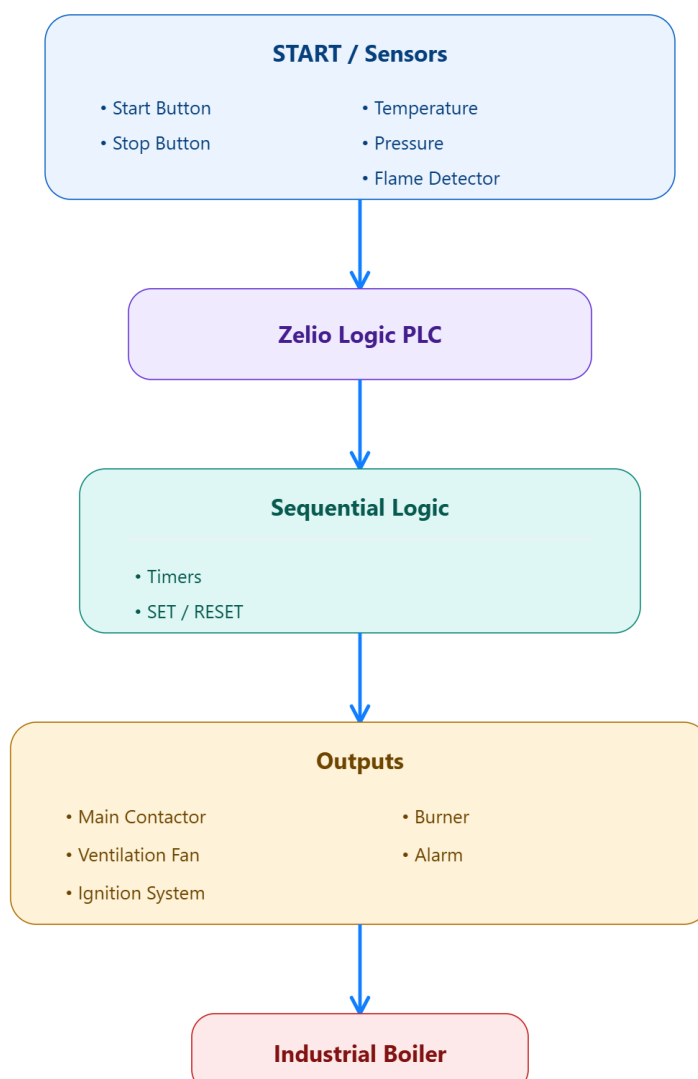


Figure 1. Industrial boiler control logic.

DESCRIPTION OF ZELIO LOGIC PLC

The Zelio Logic PLC manufactured by Schneider Electric is a compact programmable controller designed for small and medium-sized automation applications. It integrates digital inputs and outputs, internal timers, counters, memory relays, and logic functions that enable

reliable sequential process control. Programming is carried out using Zelio Soft 2 software through Function Block Diagram (FBD) or Ladder Diagram (LD), making system development straightforward while ensuring easy maintenance.

The controller is particularly suitable for industrial boiler automation because of its reliability, low implementation cost, compact architecture, and ability to execute deterministic sequential operations while complying with industrial safety requirements.

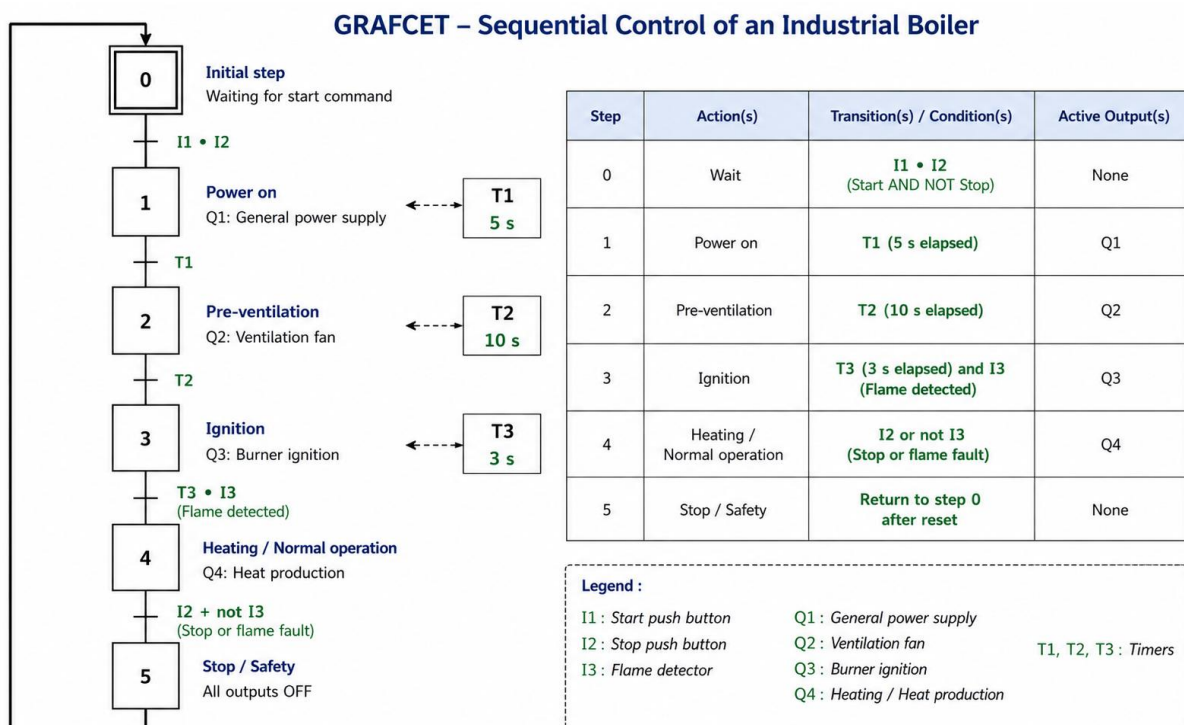


Figure 2. GRAFCET diagram of the automated operating cycle of an industrial boiler.

OPERATING PRINCIPLE

The automated cycle consists of four main phases:

Phase 1: Start-up

When the operator presses the Start button (I1), output Q1 is activated.

Phase 2: Pre-ventilation

After a delay set by Timer B1, the fan starts to exhaust residual gases from the combustion chamber.

Phase 3: Ignition

When the second timer expires, output Q2 activates the burner ignition system.

Phase 4: Heating

Once the presence of a flame is confirmed, output Q4 is activated to ensure normal boiler operation.

In the event of a shutdown or malfunction, all outputs are automatically deactivated.

PROGRAMMING WITH ZELIO SOFT

The program designed for boiler automation relies on several essential functions that work together to ensure safe and efficient operation. The SET/RESET switches act as a memory by retaining the status of each step in the process until a new condition is met.

Timers, meanwhile, ensure that the necessary time intervals between different operations are observed, particularly during the pre-ventilation, ignition, and warm-up phases. Thanks to this timing control, each action is executed at the appropriate time.

Finally, sequential logic ensures that the cycle's steps proceed in a specific order, preventing progression to the next phase until the previous one has been properly completed. This approach ensures reliable boiler operation while enhancing the safety of the system. The overall architecture of the program is shown in Figure 3.

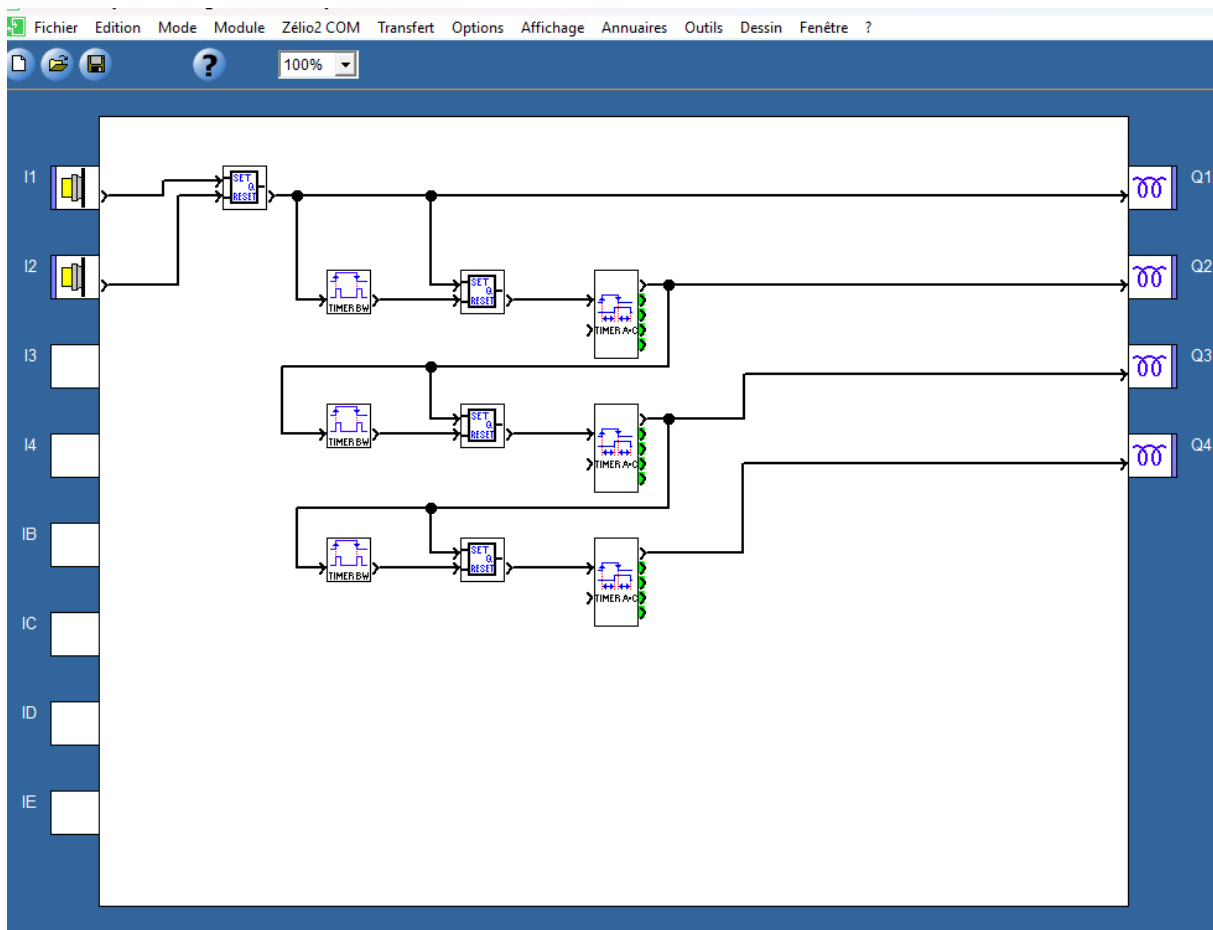


Figure 3. Sequential control program developed in Zelio Soft using the FBD language.

RESULTS AND DISCUSSIONS

Five operating scenarios were simulated in Zelio Soft 2 to verify the reliability of the proposed automation system. Under normal operating conditions, the startup sequence was executed successfully.

Safety tests demonstrated that the PLC immediately stopped the boiler whenever abnormal conditions such as flame failure, emergency stop activation, excessive temperature, or insufficient pressure were detected. These simulations confirm that the developed control strategy satisfies the essential safety requirements for industrial boiler operation.

Table 1. Program simulation results and summary of the automated boiler system's performance.

Scenario	Description	Expected Result	Simulation
Scenario 1	Normal start-up	Boiler reaches heating mode	Successful
Scenario 2	Flame not detected	Burner shutdown	Successful
Scenario 3	Emergency stop pressed	All outputs OFF	Successful
Scenario 4	High temperature	Heating interrupted	Successful
Scenario 5	Low pressure	Boiler locked for safety	Successful

CONCLUSIONS

This study enabled the design and simulation of an automated sequential control system for an industrial boiler using a Zelio Logic PLC. Using timers and latch flip-flops, the various stages of the operating cycle were automated in a simple and reliable manner, while complying with the necessary safety requirements.

The results show that the system operates correctly and stably, confirming its value for automating small- and medium-sized industrial facilities. It is therefore a solution that is both cost-effective and efficient compared to conventional control systems.

Looking ahead, this work could be enhanced by adding remote monitoring for example, via a SCADA system or IoT tools to track the boiler's operation in real time. The integration of smarter sensors would also enable better detection of anomalies and improve overall safety.

Finally, incorporating artificial intelligence could be considered to optimize energy consumption and anticipate maintenance needs, thereby making the system even more efficient and autonomous.

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Received: June 2026; Revised: July 2026; Accepted: August 2026; Published: August 2026